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POWER ANALYSIS OF FORESTRY CUTTERS FOR COMMINUTING OF WOOD WASTE IN POPLAR CLEARINGS. PART 1: ENERGY INTENSITY

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ABSTRACT

Forestry milling cutters are increasingly used in modern forest technologies for soil preparation of reforestation. In forestry in Bulgaria, although more limited, there is a tendency for introduction of this kind of machinery. Milling machines have good technological qualities, but they also have some drawbacks, such as high-energy consumption and the need of more power drive. In the present work, an experimental study to determine the energy intensity of PT-400 forest milling unit with FAE-300S multifunctional forestry tiller for comminuting of left slash in poplar clearings, was carried out. Based on the results, regression models were developed to express the energy intensity of the forestry cutter, depending on the operating conditions and speed modes of the milling unit. In conclusion, under certain operating conditions, the optimal technological regimes for the operation of the forest mills are defined.

Key words: soil preparation, poplar clearings, slash, fuel consumption.

INTRODUCTION

Soil preparation for poplar plantations establishment is among the most energy-intensive activities in technology of reforestation. A major factor in reducing the soil preparation cost is the introduction of modern technologies and machines. Depending on applied technologies and operating conditions, the cost of soil preparation may range from 1200 to 2500 €/ha (Keča and Pajić 2015, Marinov and Jordanova 2017a).

Forest cutters for site preparation of forest areas afforestation can be used for various technological operations and they may work as: a forest brush cutters for comminuting of left slash and bushes, as a rotovator for major soil cultivation, as a machine for grinding stumps and roots. In recent years in our country, in the region of Vratsa Northwest State Forestry Enterprise, for soil preparation poplar clearings were introduced two multifunctional forest cutters FAE 300 S, powered by energetic machines Prime Tech, models PT-300 and PT-400. This led to improving the quality of soil preparation and to reduce labor costs in technology of poplar plantations establishment (Marinov *at al*. 2017).

Along with positive qualities, milling machines are characterized by greater energy intensity and require more power (Hallbrook *at al*. 2006, Marinov and Jordanova 2017b). Under more extreme operating conditions, this can lead to a significant increase in energy costs and to an increase in the total cost of soil preparation. From the reference made in the Vratsa NWSF, it was established that, depending on the operating conditions, the price of the soil preparation of the poplar clearings with the milling unit PT-400 is within the range of 1350÷1800 €/ha (Marinov *et al*. 2017). A major share in the formation of this price takes fuel consumption, which is the 55÷65% of the final price for soil preparation. This shows the great importance that energy costs have in the exploitation of forestry cutters.

The aim of this study is to research the impact of major kinematics and technology factors on the energy intensity of forest cutters for comminuting of left slash, shoots and shrubs in poplar clearings.

To achieve the goal of the research, the following tasks are solved: 1/ Experimental determination of the energy costs of the PT-400 forest milling unit with FAE 300S multi-purpose milling machine for chipping of wood waste, shoots and shrubs in poplar clearings; 2/ Development of appropriate mathematical models under certain production conditions for expressing the correlation between the technological and kinematic indicators of the milling cutter and its energy intensity; 3 / Optimization of the technological process and identification of the most efficient modes of operation of the milling machine.

MATERIALS AND METHODS

OBJECT, SUBJECT AND PLACE OF STUDY

Object of the study is a self-propelled forest milling unit consisting of an energetic machine PrimeTech PT-400 and the working machine – multi-purpose forestry cutter FAE 300S-225 (Fig. 1). The power unit is equipped with a diesel engine CAT C-13, with a rated output of 310 kW (415 HP). The machine has a crawler drive system with a chain with a width of 800 mm. This ensures high passability and a high traction force of 275 kN, a low level of soil compaction – 0.35 kg/cm^2, and the possibility to working on over-wetted terrains. Two hydrostatic systems with controllable piston-axial pumps and hydro motors are used to drive the transmission and working bodies. In this way, the frequency of rotation of the milling drum can be adjusted from 0 to 500 min^{-1}. The working bodies of the milling cutter consists of 92 chisel blades, staggered around the periphery of the milling drum, with a diameter of 0.70 m and a working width of 2.30 m.

Figure 1: PT 400 specialized milling unit with FAE300S multi-purpose forestry tiller (Photo K. Marinov)

The subject of the study is the operating productivity, fuel consumption and energy intensity of the milling machine for shredding of wood waste, shoots and shrubs in poplar clearings, and surface soil cultivation up to 5–10 cm.

The study is conducted in fresh poplar clearings of habitats type $D_{2,3}$ (Raykov *at al*. 2011) on the territory of Vratsa NWSF, near to State Forestry Oryahovo and State Forestry Vidin, along the Danube River. In order to establish the working conditions and the left slash, shoots and bushes in the clearings, the categorization of poplar clearings subject to full soil preparation is used (Marinov and Jordanova 2017a), which defines 4 categories: 1st category: clearings with wood slash mass to 10 t/ha, and smaller (to 2 m) shoots and bushes with mass to 10 t/ha; 2nd category: clearings with wood slash mass to 10 t/ha, and denser and higher (over 2 m) shoots and bushes with mass over 10 t/ha; 3rd category: clearings with wood slash mass over 10 t/ha, and smaller (to 2 m) shoots and bushes with mass to 10 t/ha; 4th category: clearings with wood slash mass over 10 t/ha, and denser and higher (over 2 m) shoots and bushes with mass over 10 t/ha.

Six poplar clearings were processed for carrying out the survey. The method of sampling areas is used to determining mass of left slash and bushes in clearings. For this purpose, sample plots with dimensions 2x2m (1% of the area) are located in 1 ha area, in which wood waste and shrubs are cut and measured. In accordance with the accepted categorization of poplar clearings, three of them relate at 1st category and the other three – at 2nd category.

METHODOLOGY OF EXPERIMENTAL STUDY

For the experimental study, the method of regression analysis and experiment planning is used (Vuchkov and Stoyanov 1986). With this method the following tasks can be solved:

1/ Planning and conducting active experiment;

2/ Establishment of mathematical models to determine the basic technological and energy parameters of the research process: – operational performance and hourly fuel consumption. They are suitable for determining the parameter – relative fuel consumption per unit area with which to express the energy intensity of forestry cutter;

3/ Establishing the impact of major operating and technological factors on the studied parameters and determining of the machine optimal technological modes.

The energy intensity of milling unit is determined by the ratio between hourly fuel consumption and operating performance. The energy intensity of machine tractors aggregates is an appropriate indicator and criterion for optimizing the technological parameters and working modes of milling machines. (Marinov and Jordanova 2017b). For this purpose, the minimum energy consumption needs to be found using the following formula:

$$E_P = \frac{G_h}{W_h} \rightarrow \min , \qquad \textbf{(1)}$$

where G_h is the hourly fuel consumption, $l.h^{-1}$.

W_h – operation performance, $dka.h^{-1}$.

Study parameters

From preliminary observations it was found that the study could be conducted by planning a two-factor active experiment. The milling unit has two devices for controlling the operating modes – a device for adjusting frequency rotation of the milling drum and a hydrotransmission speed gear drive. They are suitable for selecting input control factors.

Input control factors

X_1 – speed gear of PT-400 drive machine;

X_2 – frequency rotation (revolutions) of the milling drum of FAE 300S working machine.

These factors, at constant working width of the milling cutter, have the greatest impact on energy intensity, because they directly affect the cutting speed and the working resistance. They are main factors for managing the operating modes of each milling machine These factors can be managed and maintained at a certain level during experiment, they are independent and compatible, due to these are suitable for selecting as input control factors.

The factor X_1 – speed gear drive of the milling unit is studied in the range of 1^{-st}, 2^{-nd} и 3^{-rd} gear drive. The factor X_2 – the milling drum revolutions is studied in the range of 250 min^{-1}, 375 min^{-1} и 500 min^{-1}. To facilitate data processing, natural values of the input factors are recorded with their coded values: bottom level (−1); medium level (0) and upper level (+1).

Other factors that influence on the process and affect the size of the output parameters are determined by the manufacturing conditions characteristic of cutting, soil conditions, etc. Typical habitats $D_{2,3}$ for poplar plantations establishment are situated on equal sites, along the rivers. Therefore, the study is conducted under typical production conditions, partial floodplains and flat terrains along the Danube River, with wet and deep alluvial soils. These factors can‘t be managed during the trials, but can be maintained at a certain level. Factors that can not be managed and maintained during experiments and which affect the reproducibility of experiments are: – uneven distribution of wood waste and vegetation in the clearing, change of slope, inhomogeneous soil structure, etc. In order to limit their negative impact on the reproducibility, objects that are relatively homogeneous in composition and structure are selected for experimentation.

Output parameters

In order to determine the energy intensity of the milling machine, the hourly fuel consumption and productivity were selected as output parameters. They determine the energy intensity of the milling cutter as the relative fuel consumption per unit area. They are:

- Y_1 – Operating performance, $dka.h^{-1}$;
- Y_2 – Hour fuel consumption, $l.h^{-1}$;
- Y_3 – Relative fuel consumption (energy intensity), $l.dka^{-1}$.

Methods and means for measuring and operating conditions

To determine the operating performance- Y_1, a timing of working operations is made, and the volume of the work is measured. For each experiment from the experiment plan, three experimental observations are made. The treated area is measured to the nearest 1 m^2. Fuel consumption – Y_2 is determined by directly measuring the volume of fuel consumption. At the end of each test observation, the unit chassis is setted horizontally and the engine is stopped, the fuel tank is filled to the top and the fuel volume is recorded to the nearest 0.1 liter.

The hardness of the soil is measured with a portable cone penetrometer „Wile“. For this purpose 20 test points are measured in each treated area and the mean value is determined. Soil moisture is determined by the analytical weighting method by drying soil samples in a drying oven at a temperature of 103 ± 2 °C. The mass of samples was measured with an electronic scale "Kern", with accuracy 0.01 g. For timing observations, a stopwatch is used, with accuracy 1 s. For treated area measure, a measuring tape is used, with accuracy 1 cm.

The working conditions established in the treated poplar clearings are typical for poplar habitats – type $D_{2,3}$. The soil is alluvial, clayey sandy, heavy to moderate, with density 1000÷1100 kg/m^3. The soil hardness is 1.75 MPa, with an average humidity of 27%. The terrains are planes with a slope of 2÷3 ^{o} and an altitude of 25-30 m. The configuration of the areas has a rectangular shape and the length of working strokes varies from 180 m to 250 m, which favors the movement and operation of machines. The amount of wood waste, coppice and tree-shrub vegetation in treated poplar clearings corresponds to the 1st and 2nd category.

Design of experiment

From a preliminary research it was found that the output parameters variation, according to the input parameters, is non-linear. This means that the operational performance and fuel consumption functions are described by polynomials of higher order. To conduct the experimental study a D-optimal design of experiments is selected, with two input controllable factors and with three levels of variation. Design of experiment is shown in Table 1.

Table 1: Design of experiment

№ of exper.	Input parameters			
	Coded values		Natural values	
	X1, Speed gear	X2, Milling drum revolutions	X1, Speed gear, [level]	X2, Milling drum revolutions, [min^{-1}]
1	1	1	3	500
2	1	-1	3	250
3	-1	1	1	500
4	-1	-1	1	250
5	1	0	3	375
6	-1	0	1	375
7	0	1	2	500
8	0	-1	2	250
9	0	0	2	375

From a priori information it is assumed that mathematical model expressing the output parameters functions is described by a second order polynomial and has following full form:

$$\hat{y} = b_0 + \sum_{i=1}^{m} b_i \dot{x}_i + \sum_{i<j} b_{ij} \dot{x}_i \dot{x}_j + \sum b_{ii} \dot{x}_i^2 , \qquad \textbf{(2)}$$

where $-1 < \dot{x}_i < 1$ are coded values of the input parameters and $i=1,2,...,m$;

m = 2 – number of managed input parameters;

b_0 – regression coefficient of the free member;

b_i – regression coefficients of linear members;

b_{ij} – regression coefficients of interaction between linear members;

b_{ii} – regression coefficients of square members.

RESULTS AND DISCUSSION

The data obtained from the experimental experiments were subjected to statistical processing and analysis. Computer program QstatLab has been used for computational procedures. After final data processing, the following results were obtained:

Poplar clearings 1^{-st} category. For comminuting of left slash, shoots and shrubs in poplar clearing 1st category, to determine the operating performance Y_1 and the hourly fuel consumption Y_2, following regression models were obtained:

$$Y_1 = 3.0237+0.7128x_1+0.3564x_2-0.047x_1x_1+0.0823x_2x_2+0.1116x_1x_2,\ dka.h^{-1}; \quad (3)$$

$$Y_2 = 65.96+9.85x_1-5.9x_2-1.683x_1x_1+5.067x_2x_2+1.275x_1x_2,\ l.h^{-1}; \quad (4)$$

To determine the energy intensity of the milling machine – $Y_3=Y_2/Y_1$, the following regression model was obtained:

$$Y_3 = 21.66-2.171x_1-4.765x_2+0.4018x_1x_1+1.724x_2x_2+1.019x_1x_2,\ l.dka^{-1}. \quad (5)$$

The summarized results for the studied input parameters for comminuting of slash and shrubs in 1st category poplar clearings, obtained from the experimental tests and regression models, are presented in Table 2.

Table 2: Results from experimental research in poplar clearings 1st category

№ of exp.	Input parameters				Output parameters from tests			Output parameters from models		
	Coded values		Natural values		Operating perform.	Hourly fuel cons.	Energy intensity	Operating perform.	Hourly fuel cons.	Energy intensity
	X_1	X_2	X_1	X_2, [min^{-1}]	Y_1, [$dka.h^{-1}$]	Y_2, [$l.h^{-1}$]	Y_3, [$l.dka^{-1}$]	Y_1, [$dka.h^{-1}$]	Y_2, [$l.h^{-1}$]	Y_3, [$l.dka^{-1}$]
1	1	1	3	500	4.70	81.9	17.418	4.2398	74.5639	17.8648
2	1	-1	3	250	3.21	81.0	25.258	3.3037	83.8139	25.3563
3	-1	1	1	500	2.64	53.4	20.241	2.5909	52.3139	20.1682
4	-1	-1	1	250	1.97	63.4	32.156	2.1013	66.6639	31.7352
5	1	0	3	375	3.96	80.9	20.431	3.6895	74.1222	19.8869
6	-1	0	1	375	2.22	52.7	23.733	2.2638	54.4222	24.2281
7	0	1	2	500	3.31	62.9	18.988	3.4623	65.1222	18.6148
8	0	-1	2	250	2.57	71.5	27.820	2.7495	76.9222	28.1440
9	0	0	2	375	2.86	61.9	21.601	3.0237	65.9556	21.6557

The results of the statistical data processing and the ANOVA analysis of the results for the energy intensity of the milling cutter in 1st category poplar clearings are given in Table 3.

Table 3: Results of statistical processing of data in 1st category poplar clearings

```
- ANOVA -
-------------------------------------------------------------------------------------------
Source Sqr. sum DOF Variance F P
Model 174.89494 5 34.97899 89.04668 0.00185
Residual 1.17845 3 0.39282
Total 176.07339 8
--------------------------------------------------------------------------------------------
- PRESS -
--------------------------------------------------------------------------------------------
N y yp y-yp PRESS(i) SE pred. St. residual
1 17.4188 17.8648 -0.4461 -2.2942 0.5625 -1.6141
2 25.2584 25.3563 -0.0980 -0.5038 0.5625 -0.3544
3 20.2415 20.1682 0.0733 0.3771 0.5625 0.2653
4 32.1567 31.7352 0.4215 2.1675 0.5625 1.5250
5 20.4310 19.8869 0.5441 1.2241 0.4672 1.3021
6 23.7333 24.2281 -0.4948 -1.1133 0.4672 -1.1842
7 18.9875 18.6148 0.3728 0.8387 0.4672 0.8922
8 27.8205 28.1440 -0.3235 -0.7279 0.4672 -0.7742
9 21.6065 21.6557 -0.0493 -0.1108 0.4672 -0.1179
```

T (0.025,3)=3.18245; F(0.050,5,3)=9.01346,
Residual St. Dev =0.62675; R-sq=0.99331; Radj-sq=0.98215;
PRESS = 14.34090; R-sq(pred)=0.91855

Poplar clearings 2-nd category. For shredding of wood waste, shoots and shrubs in the 2nd category poplar harvesters, the following regression models were determined to determine the operational performance Y_1 and the fuel hourly Y_2:

$$Y1 = 2.815+0.5875x1+0.282x2-0.2272x1x1+0.1018x2x2+0.0529x1x2,\ dka/h; \quad \textbf{(6)}$$

$$Y_2 = 67.53+7.4167x1-8.85x2-0.15x1x1+3.95x2x2+3.975x1x2,\ l/h. \quad \textbf{(7)}$$

To determine the energy intensity of the milling machine – $Y_3 = Y_2/Y_1$, the following regression model was obtained:

$$Y_3 = 23.88-3.382x1-6.312x2+2.768x1x1+1.293x2x2+2.775x1x2,\ l/dka. \quad \textbf{(8)}$$

The summarized results for the studied input parameters for comminuting of slash and shrubs in 2nd category poplar clearings, obtained from the experimental tests and regression models, are presented in Table 4.

Table 4: Results from experimental research in poplar clearings 2nd category

№ of exp.	Input parameters				Output parameters from tests			Output parameters from models		
	Coded values		Natural values		Coded values	Natural values	Operating perform.	Hourly fuel cons.	Energy intensity	Operating perform.
	X_1	X_2	X_1	X_2, [min^{-1}]	Y_1, [dka.h^{-1}]	Y_2, [l.h^{-1}]	Y_3, [l.dka^{-1}]	Y_1, [dka.h^{-1}]	Y_2, [l.h^{-1}]	Y_3, [l.dka^{-1}]
1	1	1	3	500	3.525	75.9	21.532	3.5185	75.7583	21.9521
2	1	-1	3	250	2.961	84.1	28.403	2.9623	84.6083	28.3795
3	-1	1	1	500	2.303	54.8	23.795	2.2965	54.175	23.7692
4	-1	-1	1	250	1.88	72.7	38.670	1.8813	72.725	38.2011
5	1	0	3	375	3.1725	76.2	24.019	3.1777	75.8333	23.6217
6	-1	0	1	375	2.021	58.5	28.946	2.0262	59.1	29.4411
7	0	1	2	500	3.0785	64.8	21.049	3.0916	65.5667	20.6548
8	0	-1	2	250	2.6085	79.8	30.592	2.6059	79.2667	31.0845
9	0	0	2	375	2.7965	68.3	24.423	2.7861	68.0667	24.3256

The results of the statistical data processing and the ANOVA analysis of the results for the energy intensity of the milling cutter in 2nd category poplar clearings are given in Table 5.

Table 5: Results of statistical processing of data in 2nd category poplar clearings

- ANOVA -

Source Sqr. sum DOF Variance F P
Model 244.48019 5 48.89604 121.43415 0.00117
Residual 1.20796 3 0.40265
Total 245.68816 8

- PRESS -

N y yp y-yp PRESS(i) SE pred. St. residual

1	21.5319	21.9521	-0.4202	-2.1612	0.5695	-1.5018
2	28.4026	28.3795	0.0231	0.1185	0.5695	0.0824
3	23.7950	23.7692	0.0259	0.1330	0.5695	0.0924
4	38.6702	38.2011	0.4691	2.4127	0.5695	1.6766
5	24.0189	23.6217	0.3972	0.8936	0.4730	0.9389
6	28.9461	29.4411	-0.4950	-1.1137	0.4730	-1.1701
7	21.0492	20.6548	0.3944	0.8873	0.4730	0.9322
8	30.5923	31.0845	-0.4922	-1.1074	0.4730	-1.1635
9	24.4234	24.3256	0.0978	0.2201	0.4730	0.2312

T(0.025,3)=3.18245; F(0.050,5,3)=9.01346
Residual St. Dev = 0.63455; R-sq=0.99508; Radj-sq=0.98689
PRESS = 14.62438; R-sq(pred)=0.94048

Data from the statistical processing show that at a level of significance $\alpha = 0.5$, the obtained regression models describe with sufficient accuracy the output parameters of the studied process. The value of the F-criteria from the ANOVA analysis used to check the significance of the multiple correlation coefficient in both models has values higher than the tabular limits and F > F (0.05,5,3) = 9.01346. This means that the regression models obtained are adequate and can be used in the studied technological processes. The index R-sq (pred) for predicting output parameters in both models is relatively high (R-sq (pred) > 0.9), which means that the proposed regression models have a good predictive properties.

The resulting mathematical models allow the operational performance, fuel consumption and energy efficiency of the PT-400 milling unit to be determined, depending on the speed gears and the milling drum revolutions of the FAE 300S forestry tiler. Based on the regression models obtained, graphical dependencies were drafted to express energy intensity of milling cutter for comminuting of slash, shoots and shrubs in poplar clearings 1st and 2nd category, with soil milling to 5–10 cm (Fig. 2 и Fig. 3).

The results of the study show that in the case of 1st category poplar clearings, the energy intensity of the milling cutter is lowest at maximum speed of the milling drum – 500 min^{-1} and when the PT-400 unit is moving on the 3rd shift gear. The relative fuel consumption in this technological mode is the lowest – 17.86 l/dka and it is the most economical in the established production conditions. The relative fuel consumption in this mode is the lowest – 17.86 l/dka and it is the most economical for these operating conditions. The optimal values of the kinematic parameters of the milling process, expressed through the input parameters, are:

- Operating forward (feed) speed of the PT-400 milling unit – $v_p = 0.51$ m/s;
- Peripheral (rotating) speed of the FAE 300/S milling drum – $v_o = 18.3$ m/s;
- Kinematic indicator – $\lambda = v_o/v_p = 35.9$.

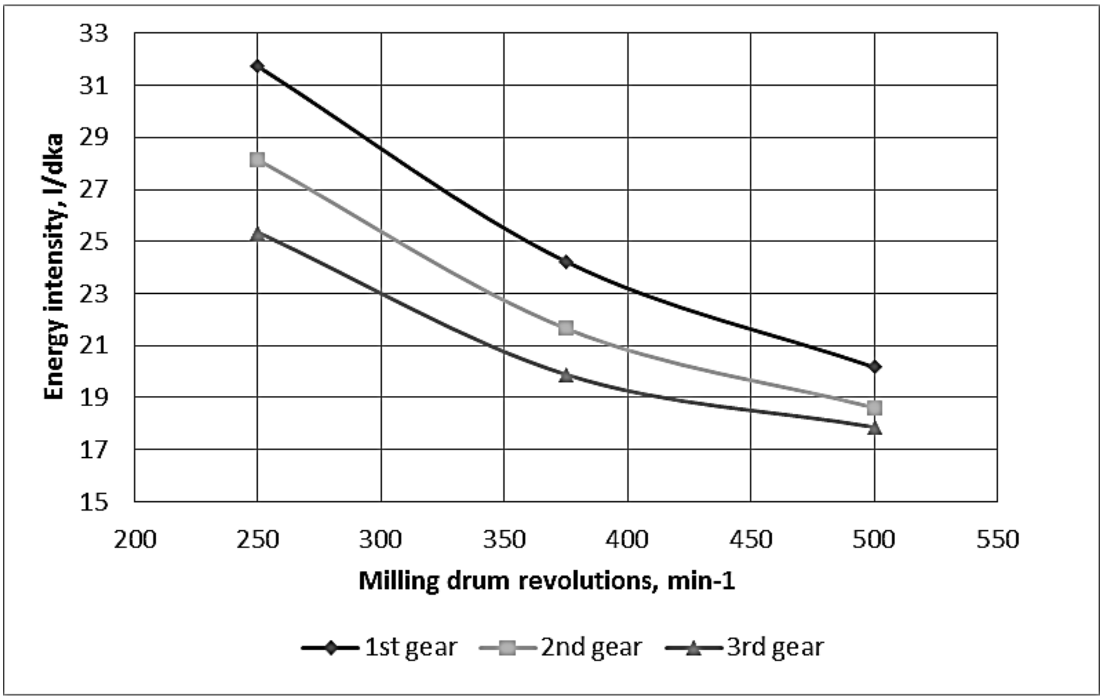

Figure 2: Variation of energy intensity of FAE 300S forestry cutter, depending on the milling drum revolutions and the speed gearshift of PT-400 milling unit for comminuting left slash, coppices and brushes in poplar clearings 1st category

The results obtained correspond to the generally accepted theory of the milling process that the increase in the feed speed of milling cutters reduces the energy intensity (Матяшин и кол., 1988). This formulation, however, changes in milling of wood and soil in poplar clearings second category, where the mass of wood residues and shrubs is greater (Fig. 3).

From the graph in Figure 3, it is seen that when milling aggregate operating on 3rd gear, the power consumption is 21.95 l/dka, and the lower fuel consumption being 20.65 l/dka when PT-400 moving the 2nd shift gear ratio. This fact is due to the increase in the overall working resistance of the power machine, resulting in a higher load and reaching the maximum engine power limit. Under these operating conditions this mode of operation is optimal. The following optimal kinematic values of the milling process are established here:

- Operating forward (feed) speed of the PT-400 milling unit – $v_p = 0.36$ m/s;
- Peripheral rotating speed of the FAE 300/S milling drum – $v_o = 18..3$ m/s;
- Kinematic indicator – $\lambda = v_o/v_p = 50.8$.

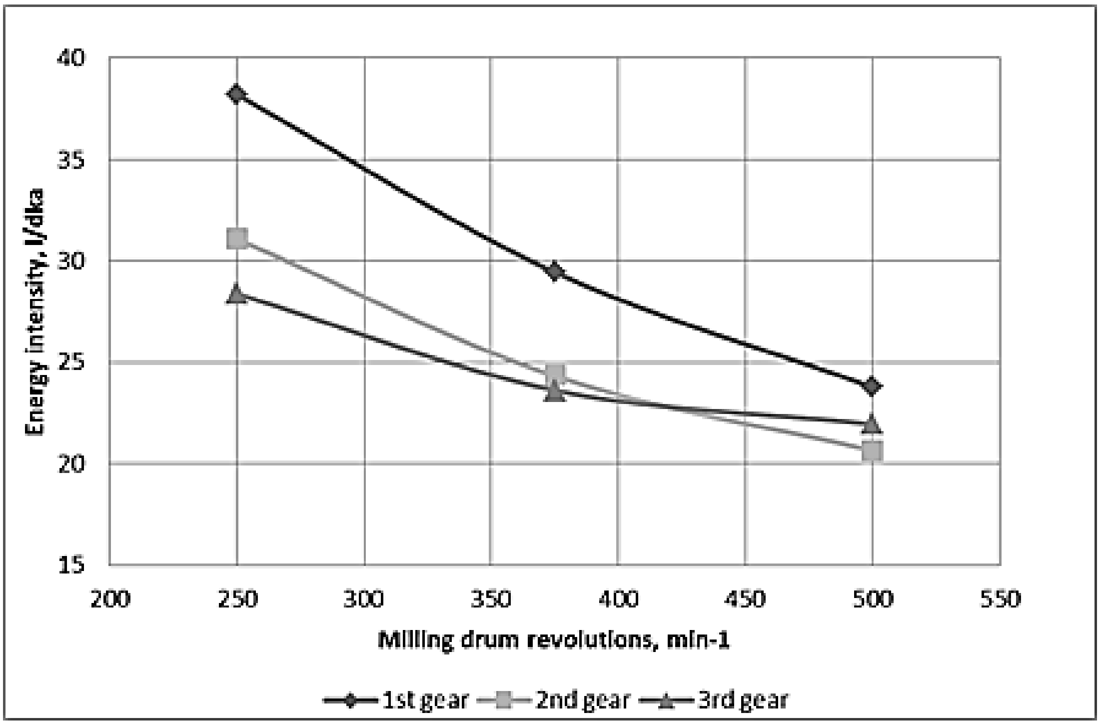

Figure 3: Variation of energy intensity of FAE 300S forestry cutter, depending on the milling drum revolutions and the speed gearshift of PT-400 milling unit for comminuting left slash, coppices and brushes in poplar clearings 2nd category

The results obtained from the experimental studies indicate that with increasing the rotation speed of the milling drum, the energy consumption decreases, which is also evident from Fig. 2 and Fig. 3. This to some extent does not correspond completely with some theoretical formulations (Matjashin *at al*. 1988, Shishkov and Daskalov 1989). This fact can be explained by the accumulation of kinetic energy into mass working bodies. Milling drums of forest cutters for soil preparation are characterized by larger masses. For example, the FAE 300S forest cutter has a full mass of 3520 kg, such as the mass of milling drum constitutes about 1/3 of it. At higher speeds of rotation of the drum in a more unloaded mode, it accumulates a significant amount of kinetic energy, which later was given in the process of milling. These specific features in the operation of forest mills require them to be reflected in the values of the dynamic and correction coefficients reflecting the dynamics of the process in the analytical dependencies.

CONCLUSION

Cultivation of poplar plantations for accelerated production of wood materials for industry has a huge economic and environmental significance. Plantation way of managing these forests requires intensive care and more full mechanization of processes. To this end, in recent years in Bulgaria, innovative technologies and machines built on the basis of forest milling machines were introduced. These machines are characterized by high technological properties, but they are more energy-intensive and require higher power. From the annual statements for complete soil preparation of poplar clearing with a PT-400 forest milling aggregate made from the Vratsa Nord-West State Forestry, it was found that the energy costs for fuel account for about 55% of the total costs. Despite the high technological qualities of milling machines, their effectiveness will depend on the achieved economic results. In order to make their operation more efficient, a complex analysis of energy, technology and financial indicators is required.

Forest milling machine for soil preparation of afforestation are still in the initial stage of operation in our country. Therefore, we still lack sufficient data on their energy properties. For this purpose, an experimental study was carried out for determining the energy intensity of a forest milling aggregates for comminuting of wood waste in poplar clearings. As a result of the conducted research we can draw the following main conclusions:

1. The energy intensity of a specialized milling machine PT-400 with FAE 300/S multi-purpose wood milling machine for comminuting of left slash, shoots and shrubs in 1st and 2nd category poplar clearing was established;
2. Mathematical models are defined to determine the energy intensity, operating property and fuel consumption of the milling machine under certain operating conditions, depending on the kinematic and technological indicators.
3. The optimal technological modes for wood waste comminuting in 1st and 2nd category poplar clearings with PT-400 forestry milling unit are determined.

The results obtained have a scientific and scientific-applied contribution. They can be used in the field of theory, design and operation of forest milling machines.

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